EMYCIN has generated a great deal of interest in the academic and business communities. We have been in frequent contact with Bud Frawley and Philippe Lacour-Gayet of Schlumberger, Milt Waxman of the Hughes Aircraft Corporation, and Harry Reinstein from IBM Scientific Research Center. of EMYCIN. Two students at the Naval Postgraduate School in Monterey, California working under the direction of Colonel Ronald J Roland are developing an EMYCIN system in the domain of selecting decision aids for solving problems in business organizations. Dr. Don Walter of UCLA in currently seeking funding for developing an EMYCIN system in the domain of diagnosis and management of epilepsy.

During the past year the MYCIN program was used in a study of debugging techniques for Artificial Intelligence systems. This work was a SUMEX Pilot project undertaken by Mitch Model as part of the work on his PhD thesis, "Understanding System Behavior in a Complex Computational Environment." Using the display LISP at Xerox PARC, Model developed a general approach and some specific tools to be used in debugging AI systems in which, for various reasons, traditional debugging tools are inadequate. The primary object of the work was the KRL-1 system; however, to test the generality of the approach, it was important to apply it to other AI systems. A mechanism was developed for communicating between two LISP jobs over the ARPANET. After minor experimentation, it was possible add this mechanism to the MYCIN program at SUMEX. Model was then able to test the generality of his approach by having MYCIN (running on SUMEX) send monitoring information over the ARPANET to his system running on MAXC computer at Xerox PARC.

We have continued collaboration with the EMYCIN-based projects RX, HEADMED and PUFF. Our development of a domain-independent system is facilitated by having a number of very different working systems on which to test our additions and modifications to EMYCIN. All the projects have provided us with useful comments and suggestions.

We have also interacted with members of the SECS project on SUMEX who are interested in developing a question answering system for SECS similar to the one in MYCIN.

C. Critique of Resource Management

The SUMEX facility has maintained the high standards that we have praised in the past. The staff members are always helpful and friendly, and work as hard to please the Sumex community as to please themselves. As a result, the computer is as accessible and easy to use as they can make it. More importantly, the machine is a reliable and convenient research tool. Special thanks to T.Rindfleisch for maintaining high professional standards for all aspects of the facility.

We continue to feel the need for more computing power. Most of our research and development takes place in the hours from 7 p.m. to 10 a.m., but it is unreasonable to expect all our collaborators to adjust their own schedules around a computer.

4.2.7 Protein Structure Project

Protein Structure Modeling Project

Prof. E. Feigenbaum and Dr. R. Engelmore
Department of Computer Science
Stanford University

I. Summary of Research Program

A. Technical goals

The goals of the protein structure modeling project are to 1) identify critical tasks in protein structure elucidation which may benefit by the application of AI problem-solving techniques, and 2) design and implement programs to perform those tasks. We have identified two principal areas which have both practical and theoretical interest to both protein crystallographers and computer scientists working in AI. The first is the problem of interpreting a three-dimensional electron density map. The second is the problem of determining a plausible structure in the absence of phase information normally inferred from experimental isomorphous replacement data. Current emphasis is on the implementation of a program for interpreting electron density maps (EDM's).

B. Medical relevance and collaboration

The biomedical relevance of protein crystallography has been well stated in an excellent textbook on the subject (Blundell & Johnson, Protein Crystallography, Academic Press, 1976):

> "Protein Crystallography is the application of the techniques of X-ray diffraction ... to crystals of one of the most important classes of biological molecules, the proteins. ... It is known that the diverse biological functions of these complex molecules are determined by and are dependent upon their three-dimensional structure and upon the ability of these structures to respond to other molecules by changes in shape. At the present time X-ray analysis of protein crystals forms the only method by which detailed structural information (in terms of the spatial coordinates of the atoms) may be obtained. The results of these analyses have provided firm structural evidence which, together with biochemical and chemical studies, immediately suggests proposals concerning the molecular basis of biological activity."

The project is a collaboration of computer scientists at Stanford University and crystallographers at the University of California at San Diego (under the direction of Prof. Joseph Kraut) and at Oak Ridge National Laboratories (Dr. Carroll Johnson). Our principal collaborator at UCSD is Dr. Stephan Freer.

C. Progress summary

We have completed a major cycle of design review and program reorganization, resulting in the system described in publication number three below. The system now has a completely rule-based control structure proceeding from strategy rules, to a set of task rules, ending with individual knowledge sources. This new design seems powerful and flexible enough to provide the basis of a useful EDM interpretation system for protein structure determination. We have also continued our efforts to improve the power of our data representations. To this end we have implemented a new preprocessor to assign functional labels to segments. This program consists of heuristics that attempt to capture the knowledge a human uses when he visually examines a skeletonized EDM. We find the use of labeled segments greatly aids the main CRYSALIS program by allowing rules to be written in terms much closer to what humans use rather than the language in which the EDM skeleton is defined.

Finally, we are compiling documentation on the system and the knowledge it embodies. These documents should be complete enough that we, or another group, will have little difficulty picking up where we leave off. We also feel that explicit documentation of our model-building heuristics will be useful to the crystallographic community as they provide a new viewpoint, complementary to their traditional methods.

D. List of Publications

1) Robert S. Engelmore and H. Penny Nii, "A Knowledge-Based System for the Interpretation of Protein X-Ray Crystallographic Data," Heuristic Programming Project Memo HPP-77-2, January, 1977. (Alternate identification: STAN-CS-77-589)

2) E.A. Feigenbaum, R.S. Engelmore, C.K. Johnson, "A Correlation Between Crystallographic Computing and Artificial Intelligence," in Acta Crystallographica, A33:13, (1977). (Alternate identification: HPP-77-25)

3) Robert Engelmore and Allan Terry, "Structure and Function of the CRYSALIS System," paper accepted for presentation at IJCAI-79.

II. Interaction with the SUMEX-AIM resource

A. Collaborations

The protein structure modeling project has been a collaborative effort since its inception, involving co-workers at Stanford and UCSD (and, more recently, at Oak Ridge). The SUMEX facility has provided a focus for the communication of knowledge, programs and data. Without the special facilities provided by SUMEX the research would be seriously impeded. Computer networking has been especially effective in facilitating the transfer of information. For example, the more traditional computational analyses of the UCSD crystallographic data are made at the CDC 7600 facility at Berkeley. As the processed data, specifically the EDM's and their Fourier transforms, become available, they are transferred to SUMEX via the FTP facility of the ARPA net, with a minimum of fuss. (Unfortunately, other methods of data transfer are often necessary as well -- see below.) Programs developed at SUMEX, or transferred to SUMEX from other laboratories, are shared directly among the collaborators. Indeed, with some of the programs which have originated at UCSD and elsewhere, our off-campus collaborators frequently find it easier to use the SUMEX versions because of the interactive computing environment and ease of access. Advice, progress reports, new ideas, general information, etc. are communicated via the message and/or bulletin board facilities.

B. Interaction with other SUMEX-AIM projects

Our interactions with other SUMEX-AIM projects have been mostly in the form of personal contacts. We have strong ties to the DENDRAL, Meta-DENDRAL and MOLGEN projects and keep abreast of research in those areas on a regular basis through informal discussions. The SUMEX-AIM workshops provide an excellent opportunity to survey all the projects in the community. Common research themes, e.g. knowledge-based systems, as well as alternate problem-solving methodologies were particularly valuable to share.

C. Critique of Resource Services

The SUMEX facility provides a wide spectrum of computing services which are genuinely useful to our project -- message handling, file management, Interlisp, Fortran and text editors come immediately to mind. Moreover, the staff, particularly the operators, are to be commended for their willingness to help solve special problems (e.g., reading tapes) or providing extra service (e.g. immediate retrieval of an archived file). Such cooperative behavior is rare in computer centers.

It has become increasingly evident, however, that as CRYSALIS expands, the facility cannot provide enough machine cycles during prime time to support the implementation and debugging of new features. For example, our segment-labeling preprocessor requires about an hour of machine time per 100 residues of protein (this is typically five to eight hours of terminal time during working hours) even when the Lisp code is compiled.

A continuing deficiency is the lack of even a rudimentary file transfer facility between SUMEX and the computing system in the UCSD Chemistry Department. Our day-to-day collaboration with Dr. Freer at UCSD would be greatly enhanced by a DIALNET or similar low-cost facility.

III. Use of SUMEX during the remaining grant period (8/79 - 7/81)

A. Long-range goals

Our current research grant ended on April 30, 1979, with a six-month finishing-up period. Due to the transfer of Dr. Engelmore to the Defense Advanced Research Projects Agency for a two year term, it was decided by the principal investigator to withdraw the pending renewal application. However, the expected utility of the CRYSALIS system is well recognized, and has generated many requests, from both the AI and protein-crystallographic communities, to preserve the research for future resumption. As stated earlier, a documentation effort is in progress to effect that preservation. It is hoped that the work will be resumed after a two year hiatus.

The long range goals continue to be to exploit the rule-based control structure for investigating alternative problem-solving strategies, to investigate modes of explanation of the program's reasoning steps, and to expand and generalize the system to cover a wider range of input data.

B. Justification for continued use of SUMEX

During the next few months, efforts will continue to complete an extensive documentation of the CRYSALIS system, support programs, and data file structures. This documentation will be transferred to UCSD, ORNL and Carnegie-Mellon University, who have requested it, and other interested institutions. Also, some small use of SUMEX will be made for occasional file transfers to other computing facilities.

4.2.8 RX Project

The RX Project: Inferring Knowledge from Clinical Data Banks Utilizing Techniques from Artificial Intelligence

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Stanford School of Medicine

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Stanford University

I. Summary of Research Program

A. Technical goals:

Introduction:

The RX Project is a new member of the SUMEX community, having been accorded its current status as an autonomous project only as of February, 1979. Since RX is a new research project, we shall focus on the goals and medical relevance of the Project, only touching lightly on the other topics of the outline.

I. SUMMARY OF RESEARCH PROGRAM

Medical and Computer Science Goals

The objective of the RX Project is to develop a prototype computer-based system for reliably extracting knowledge pertaining to the evolution and treatment of chronic diseases from data in patient records stored in the form of computerized clinical data banks.

Computerized clinical data banks and automated medical records keeping have been major research concerns in many parts of the United States for at least a couple of decades. Among the earliest data banking endeavors was the ARAMIS Project, which has been under development at Stanford by Dr. James Fries and his colleagues since 1967. A prototype ambulatory records system was generalized in the early 1970's by Prof. Gio Wiederhold and Stephen Weyl in the form of a Time-Oriented Database (TOD) System. The TOD System, run on the IBM 370/168 at the Stanford Center for Information Processing (SCIP), now supports the ARAMIS Data Bank (American Rheumatism Association Medical Information System) as well as a host of other chronic disease data banks which store patient data gathered at many institutions nation-wide. At the present time ARAMIS contains records of over 10,000 patients with a variety of rheumatologic diagnoses. Over 30,000 patient visits have been recorded, accounting for 20,000 patient-years of observation.

The fundamental objective of ARAMIS, the other TOD research groups, and all other clinical data bank researchers is to use the raw data which has been gathered by clinical observation in order to study the evolution and medical management of chronic diseases. Unfortunately, the process of reliably extracting knowledge from raw data has proved to be refractory to existing techniques because of problems stemming from the complexity of disease, therapy, and outcome definitions; the complexity of time relationships; potential biases in compared subsets; and problems of missing and outlying data.

A major objective of the RX Project is to explore the utility of symbolic computational methods and knowledge-based techniques at solving this problem of accurate knowledge inference from non-randomized, non-protocol patient records. The methodology employed by the RX Project involves the use of a frame-based medical knowledge base conceptually similar to that developed by the KRL and MOLGEN research groups of the Heuristic Programming Project. The frame-based organization, in which disease states corresponding to individual conceptual units will be hierarchically organized, provides a major tool for increasing the homogeneity of patient subsets. Embedded within the knowledge base will be production rules containing time-dependent predicates for use in transforming the set of raw data into a collection of meaningful clinical events. This process of conceptual abstraction will make subsequent statistical analysis far less sensitive to missing or outlying data.

A second objective of the RX Project is to use its knowledge base to mediate interactive consultation with a clinician. In other words, the knowledge base is called upon both to extract and store new knowledge from a clinical data bank and to use that knowledge to facilitate interactive consultation. From the start this objective has guided selection of appropriate methods for knowledge representation and choice of control structures.

As a test bed for system development we intend to focus attention on the 270 records of patients with systemic lupus erythematosus (SLE) contained in the Stanford portion of the ARAMIS Data Bank. SLE is a major multi-system chronic rheumatologic disease with a broad spectrum of manifestations and can lead to death in the third decade of life. With many perplexing diagnostic and therapeutic dilemmas, it is a disease of considerable medical interest.

In the future we anticipate the development of collaborative arrangements with other project users of the TOD System such as the National Stroke Data Bank, the Northern California Oncology Group, and the Stanford Divisions of Oncology and of Radiation Therapy.

The RX Project is a new research effort only in existence for less than a year, and, hence the project is very much in a developmental stage. The primary issues being addressed at this stage are those concerned with the specifics of knowledge representation and flow of control, rather than with the testing of specific hypotheses in chronic disease management.

We believe that this research project is broadly applicable to the entire gamut of chronic diseases which constitute the bulk of morbidity and mortality in the United States. Consider five major diagnostic categories which are responsible for approximately two thirds of the two million deaths per year in the United States: myocardial infarction, stroke, cancer, hypertension, and diabetes. Therapy for each of these diagnoses is fraught with controversy concerning the balance of benefits versus costs.

1) Myocardial Infarction: Indications for and efficacy of coronary artery bypass graft vs. medical management alone. Indications for long-term antiarrhythmics ... long-term anticoagulants. Benefits of cholesterol-lowering diets, exercise, etc.

2) Stroke: Efficacy of long-term anti-platelet agents, long-term anticoagulation. Indications for revascularization.

3) Cancer: Relative efficacy of radiation therapy, chemotherapy, surgical excision - singly or in combination. Optimal frequency of screening procedures. Prophylactic therapy.

4) Hypertension: Indications for therapy. Efficacy versus adverse effects of chronic antihypertensive drugs. Role of various diagnostic tests such as renal arteriography in work-up.

5) Diabetes: Influence of insulin administration on microvascular complications. Role of oral hypoglycemics.

Despite the expenditure of billions of dollars over recent years for randomized controlled trials (RCT's) designed to answer these and other questions, answers have been slow in coming. RCT's are expensive of funds and personnel. The therapeutic questions in clinical medicine are too numerous for each to be addressed by its own series of RCT's.

On the other hand, the data regularly gathered in patient records in the course of the normal performance of health care delivery is a rich and largely underutilized resource. The ease of accessibility and manipulation of these data afforded by computerized clinical data banks holds out the possibility of a major new resource for acquiring knowledge on the evolution and therapy of chronic diseases.

The goal of the research which we are pursuing on SUMEX is to increase the reliability of knowledge derived from clinical data banks with the hope of providing a new tool for augmenting knowledge of diseases and therapies as a supplement to knowledge derived from formal prospective clinical trials. Furthermore, the incorporation of knowledge from both clinical data banks and other sources into a uniform knowledge base should increase the ease of access by individual clinicians to this knowledge and thereby facilitate both the practice of medicine as well as the investigation of human disease processes.

Progress Summary

The initial testbed for the RX Project will be a subset of the clinical records stored in the ARAMIS Data Bank. These data are available to us on the Stanford Center for Information Processing (SCIP) IBM 370/168 on which ARAMIS is resident. Mr. Ron Code of the SCIP Staff has written a program for formatting this data into a form suitable for transfer to SUMEX. Transfer of patient records from SCIP to SUMEX is currently implemented via the "TRAN" line, a 2400 baud local hardline.

A record package has been implemented at SUMEX to transform the time-oriented data from ARAMIS into a form suitable for further transformation - the conceptual abstraction, which we have described previously. The algorithms for conceptual abstraction have been developed, and the data structures for storing medical knowledge and abstracted records have been worked out in detail. Programs implementing these algorithms are underway.

Algorithms for statistical manipulation of the abstracted patient records have been developed in collaboration with Mr. Guy Kraines, biostatistician for ARAMIS, and Prof. Byron Brown, Chairman of Biostatistics at the Stanford Medical Center. Methods will include multivariate, logistic regression and Cox model regression for time-dependent parameters.

Publications

Blum, Robert L.; Wiederhold, Gio: Inferring Knowledge from Clinical Data Banks Utilizing Techniques from Artificial Intelligence. Proc. of The 2nd Annual Symp. on Computer Applications in Medical Care, pp. 303 to 307, IEEE, Washington, D.C., November 5-9, 1978.

II. INTERACTIONS WITH THE SUMEX-AIM RESOURCE

Collaborations

Since our project is new, we have not yet developed programs which may be used by others. There is, however, a tremendous sphere of collaboration which we expect in the future. Once the RX program is developed, we would anticipate collaboration with all of the ARAMIS project sites in the further development of a knowledge base pertaining to the chronic arthritides. The ARAMIS Project at SCIP is used by a number of institutions around the country via commercial leased lines to store and process their data. These institutions include the University of California School of Medicine, San Francisco and Los Angeles; The Phoenix Arthritis Center, Phoenix; The University of Cincinnati School of Medicine; The University of Pittsburgh School of Medicine; Kansas University; and The University of Saskatchewan. All of the rheumatologists at these sites have closely collaborated with the development of ARAMIS, and their interest in and use of the RX project is anticipated. We hasten to mention that we do not expect SUMEX to support the active use of RX as an on-going service to this extensive network of arthritis centers, but we would like to be able to allow the national centers to participate in the development of the arthritis knowledge base and to test that knowledge base on their own clinical data banks.

III. RESEARCH PLANS

Project Plans (August 79 to July 81)

During the next year we will continue to develop the basic software needed to implement the "conceptual abstraction" algorithms and programs need for manipulation of the time-oriented records. We will elaborate a preliminary frame-structured knowledge base pertaining to systemic lupus erythematosus (SLE).

During the following year - August, 80 to July, 81 - we expect to populate the knowledge base using probabilities derived from the time-oriented records of the 270 patients with SLE. We will begin to investigate specific disease questions pertaining to SLE using records from the other ARAMIS institutions. Among these dilemmas are

1) the role of immunosuppressive therapy as adjunctive therapy for aggressive lupus nephritis,

2) the role of renal biopsy in the management of lupus nephritis,

3) the indications for and optimal administration of steroid therapy,

4) the usefulness of serologic indices as a guide to therapy.

Justification for Continued Use of SUMEX

Although we have just stated the following justifications in our recent application for autonomous project status to the SUMEX Advisory Board, we shall repeat them here for emphasis.

Computerized clinical data banks possess enormous potential as tools for assessing the efficacy of new diagnostic and therapeutic modalities, for monitoring the quality of health care delivery, and for support of basic medical research. Because of this potential, many clinical data banks have recently been developed throughout the United States. However, once the initial problems of data acquisition, storage, and retrieval have been dealt with, there remains a set of complex problems inherent in the task of accurately inferring medical knowledge from a collection of observations in patient records. These problems concern the complexity of disease and outcome definitions, the complexity of time relationships, potential biases in compared subsets, and missing and outlying data. Concisely stated, the major problem of medical data banking is in the reliable inference of medical knowledge from primary observational data.

We see in the RX Project a method of solution to this problem through the utilization of knowledge engineering techniques from artificial intelligence. The RX Project, in providing this solution, will provide an important conceptual and technologic link to a large community of medical research groups involved in the treatment and study of the chronic arthritides throughout the United States and Canada, who are presently using the ARAMIS Data Bank through the SCIP facility via TELENET.

Beyond the arthritis centers which we have mentioned in this report, the TOD (Time-Oriented Data Base) User Group involves a broad range of university and community medical institutions involved in the treatment of cancer, stroke, cardiovascular disease, nephrologic disease, and others. Through the RX Project, the opportunity will be provided to foster national collaborations with these research groups and to provide a major arena in which to demonstrate the utility of artificial intelligence to clinical medicine.

SUMEX as a Resource

To discuss SUMEX as a resource for program development, one need only compare it to the environment provided by our other resource, the IBM 370/168 installation at SCIP - the major computing resource at Stanford. Of the programs which we use daily on SUMEX -INTERLISP, MSG, TVEDIT, BBD, LINK- there is nothing even approaching equivalence on the 370, despite its huge user community. These programs greatly facilitate communication with other researchers in the SUMEX community, documentation of our programs, and the rapid interactive development of the programs themselves. The development of a program involving extensive symbolic processing and as large and complex as RX at the SCIP facility, would require a staff many times as large as ours. The SUMEX environment greatly increases the productive potential of a research group such as ours to the point where a large project like RX becomes feasible.

Other Computational Resources

It is clear that the scope of potential application of the RX Project is vast. Even within the term of the current SUMEX-AIM grant period through July, 1981, we anticipate the involvement of several of the national ARAMIS collaborating institutions in developing and testing arthritis knowledge bases which reflect their own patient populations and therapeutic biases. The current SUMEX machine configuration will not be able to support this national interaction because the central processors of the KI-10 are already taxed to the limit. Ours is among the SUMEX groups which would greatly benefit by the addition of one or more PDP-10 compatible machines, which could provide dedicated support to our anticipated national user community. Another resource which we will need shortly is a faster and more reliable means for transferring data interactively between SUMEX and the SCIP IBM 370. Our current method utilizes a 2400 baud line with transmission from SCIP to SUMEX only, and is fraught with a high error rate. This is adequate for the current period of software development, when data can be checked by hand; but will be useless for bulk transfer of patient data, as will be needed when other data banks need to be rapidly processed.

4.3 Pilot AIM Projects

The following are descriptions of the informal pilot projects currently using the AIM portion of the SUMEX-AIM resource pending funding, and full review and authorization.

4.3.1 Communication Enhancement Project

Communication Enhancement Project

John B. Eulenberg and Carl V. Page
Michigan State University

I) Summary of Research Program.

A) Technical goals.

The major goal of this research is the design of intelligent speech prostheses for persons who experience severe communication handicaps. Essential subgoals are:

(1) Design of input devices which can be used by persons whose movement is greatly restricted.

(2) Development of software for text-to-speech production.

(3) Research in knowledge representations for syntax and semantics of spoken English in restricted real world domains.

(4) Development of micro-computer based portable speech prostheses.

B) Medical Relevance and Collaboration.

Members of our group are in touch with Dr. Kenneth Colby and his group at UCLA who have been working on similar problems for people who have aphasia.

The need for such technology in the medical area is very great. Millions of people around the world lead isolated existences unable to communicate because of stroke, traumatic brain injury, cerebral palsy or other causes. The availability of inexpensive micro-processors and voice synthesizers allows development of complex experimental systems to study human communication. The knowledge gained from these experimental systems should lead in a few years to prototypes of very low cost which will permit many people to engage in the vital acts of communication required for a "normal" life in human society.

Despite the importance of the problems in this area, it has been difficult to coordinate the many professions which are involved. We believe that both research and the support of research in this area suffers from the lack of an identifiable community of workers. To alleviate this problem, we have joined with the Trace Center of the U. of Wisconsin to publish the first newsletter for dissemination in this area Called "Communication Outlook", the first issue was published in April, 1978. There are now over 1100 paid subscribers. Subscribers and contributors to the Newsletter come from a vide variety of disciplines and from many countries. John B. Eulenberg helped to organize the first Federal workshop for governmental agencies who have some interest in funding work in these areas. Represented were the Bureau of Education for the Handicapped, The Veterans Administration, The Civil Service Commission, NIH, NSF, and others. We have also been in touch with United Cerebral Palsy associations at the state and national levels. Much of our effort has been in educating those medical, educational, and governmental communities with an interest in this area on the available technology since most of them are not accustomed to funding the development of high-technology systems.

C) Progress summary.
Although some facets of the research have been underway at MSU for several years, we have been using SUMEX-AIM for two years, having received our password in March, 1977.

During the last past two years, we have:

1) Organized a research team of 4 students possessing background in artificial intelligence lead by Dr. Carl V. Page to start a semantics-speech generator. This group had a very primitive prototype (written in Sail) running in June, 1977. The system uses statistical, grammatical and semantic information to generate sentences by anticipation. A similar group was organized in 1978 but it produced well documented but not fully debugged programs. One of the students from the original group expects to work on the project this summer. 2) Converted a large program (Orthophone) for English text to speech synthesizer codes to SAIL from Algol.

3) Obtained local support for terminals and space to use the SUMEX-AIM facility. At present, the lack of a dedicated tie-line from East Lansing to Tymshare in Ann Arbor or Detroit is a problem for us during 0600 to 0900 PST.

4) Last year, Dr. Reid of our project designed and built a wheel-chair portable personal communication system for a 10 year old boy who has cerebral palsy. It is micro-computer based and can accept inputs via an adaptive switch from a series of menus displayed on a TV screen, via Morse code, or by a keyboard. Its outputs can be TV display, hard copy, spoken English, Morse code, or musical sounds. As the memory available for small systems will soon be substantial, we will need to specify the content and connection of the choice menus using the knowledge gained in our SUMEX-AIM project. Although our prototype for semantic generation has not run satisfactorily, it has influenced the design of the next system, the "SAL" board for wheel-chairs described below. 5) This year a communication aid using knowledge sources has been built into a lap board. Called the "SAL" prosthesis (Semantically accessible language), it uses a magnetic input to translate Bliss symbols into spoken language. Some ideas from the grammatical portions of our SUMEX-AIM project have found their way into the SAL system. The SAL system consists of an aluminum encased lap tray with an array of 252 reed switches arranged in a 12 row by 21 column matrix. Spacing between switches is one inch. They are activated by a small magnet held by the user on a mitt or a finger splint. The keyboard is interfaced to a Southwest Technical Products 6800 computer possessing 8K of EPROM and 8K of RAM. Voice output is from a Votrax VS-6 sound synthesizer while visual output is provided by a LED array. The current system allows 512 lexical items. Frame cells provide a choice of syntactic frame, which the user may specify at the inception of the formation of a sentence to supply structural information. Each syntactic frame is a skeletal syntactic phrase marker representing a class of sentence structures. After choosing a given syntactic frame, the user goes on to choose the lexical items. The generation of appropriate pronouns depends on

their role in the sentence. Thus the Bliss symbol for the speaker will come out "I" or "me" depending on the role. The system uses syntactic, phonetic, and orthographic features of previous inputs in order to generate its outputs. We expect to gain experience from our SUMEX-AIM prototype to guide the choice of semantics for the successors of this system. 6) Dr. John Eulenberg will be taking his Sabbatical leave in Palo Alto beginning in September, 1979. He will be associated with the Childrens' Hospital at Stanford and Telesensory Systems Inc. We have found in the past that SUMEX-AIM has provided us with a means to communicate with other members of our project when they were California. It is very important for the many ongoing projects which we have to be able keep Dr. Eulenberg in close communication with the rest of our project during his leave.

7) We have built and tested a myoelectric interface and used it (together with a miniature FM transmitter) for input of changing muscle potentials into a computer. There is reason to believe that this means of input may provide a higher bit rate than other known means for those people who possess severe cerebral palsy.

8) We continue to develop basic educational software for severely impaired persons. For example we have developed a "talking" system for drilling students in Bliss symbolics. Another system we have developed teaches spelling using a voice synthesizer and TV screen. A classroom in a Northville, Michigan public school now contains a Nova 2/10 for the evaluation of our systems.

D) Up-to-date list of publications. (1976 to date)
By John B. Eulenberg

"Technical Systems Development, Headin", Interim Report, April, 1976, Experimental Applications of Two-Way Cable Delivery, NSF Grant No. APR 75-14286.

"Interactive New Hired Information Access System with Both Voice and Hard Copy Output: User's Guide to NHQUERRY", April 11, 1976 (With Steven Kludt and Jerome Jackson (Artificial Language Laboratory Report AEB 041176))

"Language Individualization in a Computer-Based Speech Prosthesis System", National Computer Conference, New York, June 9, 1976.

"Individualization in a Speech Prosthesis System", Proceedings of 1976 Conference on Systems and Devices for the Disabled, June 10, 1976.

"The LEAF Language", Interim Report, September, 1976, NSF Grant No. APR 75-14286.

"Microprocessor-Based Artificial Language for Communication Prostheses", with M. R. Rahimi, Proc. of the National Electronics Conference, Vol. XXXI, October, 1977.

"A programmable Multi-Channel Modem Output Switch", September 22, 1976, with Joseph C. Gehman and Juha Koljonen (Artificial Language Laboratory Report AEB 092276)

"SMPTE Time Code Interface and Computer-Controlled Video Switcher", with Michael Gorbutt and Dennis Phillips, Interim Report, March, 1977 NSF Grant APR 75-14286.

"Representation of Language Space in Speech Prostheses", with R. Reid and M. Rahimi, Proc. of Fourth Annual Conference on Systems and Devices for the Disabled, June, 1977.

"Administration and Management of a Computer-Based Communication Enhancement Program", with M. R. Rahimi and L. Neiswander, Proc. of Amer. Acad. for Cerebral Palsy and Developmental Medicine, October, 1977. "When [-VOICE] becomes [+VOICE]- The Phonological Competence of People Who Cannot Speak", with Carol Myers Scotton, Proceedings of the Annual Confer. of the Linguistic Soc. of America, December, 1977.

"Toward a Semantically Accessible Communication Aid", (With M. A Rahimi) Proceedings of the National Electronics Conference, Vol. xxxii, Chicago, Illinois, October, 1978.

By Carl V. Page:

"Heuristics for Signature Table Analysis as a Pattern Recognition Technique", IEEE Transactions on Systems, Man and Cybernetics,Vol. SMC-7, No. 2, February 1977.

"Discriminant Grammars, an Alternative to Parsing". with Alan Filipski, Proceedings of the IEEE Workshop on Picture Processing, Computer Graphics, and Pattern Recognition, April 22, 1977. "Pattern Recognition and Data structures". Chapter in "Data Structures in Computer Graphics and Pattern Recognition" Edited by Allen Klinger, Academic Press, 1977. "A Survey of Artificial Intelligence in Computer-Aided Instruction", with Alice Gable (To appear in the International Journal of Man-Machine Systems, 1979) "Economic Consequences of Robots Possessing Computer Vision Systems", Proceedings of the Upper-Midwest Small College Computer Conference, St. Cloud State University, St. Cloud, Minn. April, 1979.

II. INTERACTION WITH SUMEX-AIM RESOURCE

A. Collaborations and medical use of programs via SUMEX.

We have shown Mycin and Puff to physicians and clinical staff and discussions continue with them concerning possible research. During a visit to our campus in October, Dr. Bruce Buchanan lectured on Mycin and stimulated some of our Medical School faculty to explore research opportunities with us. As a consequence, Dr. Carl V. Page has participated in a proposal to NSF with Dr. Su-Wah Chan (principal investigator) titled "A Structural Analysis of Problem Complexity in Information Processing Behaviors as Related to Human Problem Solving". We hope that some other research possibilities derive from this effort.

B. Sharing and interactions with other SUMEX-AIM projects.
During the past year we have had personal contact with the SUMEX-AIM staff. Dr. Eulenberg attended the 1978 Workshop in the Summer. Dr. Page used the facility while working in California as a means keep in touch with the project in East Lansing. The communication aspect of the project has been useful for us in the past and will continue to be so in the future inasmuch as Dr. Eulenberg with be spending his Sabbatical in Palo Alto.

C. Critique of resource management.

We have found the staff to be professional and helpful. We have not used the system enough to comment on the management of the facility except to say that we have become somewhat disillusioned with the SAIL compiler.

III. RESEARCH PLANS (8/79-7/81)

A. Long Range project goals and plans.

We will continue to explore the interactions of different knowledge sources in the problem of generation of language. Such information as is learned will be scaled down so that it can be used in the design of portable, intelligent, speech prostheses.

B. Justification and requirements for continued SUMEX use.
We do not require any more resources than we have had in the past. Unfortunately our SUMEX research has not had the priority with us that it deserves. In one sense, our SUMEX research represents to us the future of work in this area, but we are involved with commitments for systems for communication enhancement that must be delivered soon. We expect to change the pattern of our funding to

emphasize the kinds of problems we have addressed to SUMEX, beginning the process next year. Our prototype system on SUMEX has been built by volunteer student effort rather than our financial support. We hope to change this policy when pressing needs are satisfied. Our prototype has already has had some influence on the design of a wheel-chair portable system, the SAL prosthesis mentioned above. We have planned to incorporate at least one Ph. D. thesis into this research area. One of our former employees, Mr. Douglas Appelt has been doing his thesis in this area at Stanford and we believe that it is a good area. However, before we can advise a a student to start a thesis dependent on the system, we need assurance that we will have access to SUMEX for at least two years at some reasonable level comparable to what we have now.

C. Other Computational needs.

We use minicomputers and the central computers at MSU in addition to SUMEX. We have no plans to secure any additional equipment.

D. Recommendations for future community and resource development.

1. We have not heard much lately about the KRL language. If it is available or can be made available, we would be interested in considering it for our project.

2. We would be interested programs to help scale down a system developed on SUMEX-AIM to smaller machines.

3. We are interested in programs to facilitate the hardware design process for microcomputer based systems.

4.3.2 Computerized Psychopharmacology Advisor

A Computerized Psychopharmacology Advisor

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I. Summary Research Program

A. Technical Goals.

We are developing a computer-based automated system for education and consultation in clinical psychopharmacology. Our technical goals are envisioned in three phases:

- To develop a theory of expert teaching, consulting and decision-making in clinical psychopharmacology.
- To model this theory on a computer system which responds in real time and communicates in natural language.
- To evaluate this theory and model as a representation of psychiatric knowledge by analyzing both the performance of the system and the effort required for the system's development.

B. Medical Relevance and Collaboration.

1. Medical Relevance.

For many years, it has been recognized that potent psychopharmacological agents are frequently used in an unsystematic manner. There are at least 50 discrete syndromes currently identified in clinical psychiatry which have unique hierarchies of plausible pharmacological treatments. Each therapeutic regimen in each hierarchy may involve several classes of drugs which can often be preferentially ranked. A particular member of a class of drugs may be recommended on the basis of a patient's medical history, family history, response to previous treatments, current physical status, or current mental status. In addition, each treatment program has its own set of potential side effects, adverse reactions and drug-drug, drug-host, drug-age, drug-gender, drug-state of health, and drug-other treatment interactions.

Conventional sources of information for education or verification (books, journals, lectures, and seminars) are seldom quickly accessible or specifically pertinent. A traditional alternative is to consult a specialist. In addition to availability, reliability and validity, a good consultant has the ability to understand questions in their proper context and sequence, to give advice which can be explained or documented as needed, and to provide follow-up consultations which incorporate new information from clinical developments or additional expertise.

Our research on the Clinical Psychopharmacology Advisor is directed towards implementing all of the characteristics of a good consultant, which have only been outlined above, in a functional computer program. To our knowledge, no other computer program currently available, or under development, is pursuing all of these goals in clinical psychopharmacology.

2. Collaboration.

2.1 Principal Investigator: Jon F. Heiser, M.D., Associate Professor, Department of Psychiatry and Behavioral Sciences

2.2 Co-principal Investigator: Ruven E. Brooks, Ph.D., Assistant Professor, Department of Psychiatry and Behavioral Sciences

2.3 Pharmacist, University of Texas Medical Branch: Carla Maria Brandt, B.S. (January 1979-present)

2.4 Resident Physician, Department of Psychiatry and Behavioral Sciences: Rao Chalasani, M.D. (April-June,1979)

2.5 National Advisory Panel:

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C. Progress Summary.

After carefully reviewing alternative contexts in which to generate the Psychopharmacology Advisor, we selected the EMYCIN software. MYCIN is a computer program which functions as a consultant in the diagnosis and treatment of infectious diseases. EMYCIN is a version of the MYCIN system with all the knowledge and references to infectious disease removed but with all the features for diagnosis, treatment recommendation, explanation and knowledge acquisition retained. Our choice of EMYCIN was determined by the availability of the EMYCIN software (including a significant amount of professional consultation, collaboration and system maintenance supplied by the MYCIN staff), the suitability of EMYCIN to most of our initial design considerations, and the desire of the MYCIN staff to test the EMYCIN software in a different clinical domain. EMYCIN has thus become our working theory and model of expert teaching, consulting and decision-making in clinical psychopharmacology.

Our initial goal was to develop a small, but fully functioning, Clinical Psychopharmacology Advisor. Approximately 250 rules, utilizing about 120 clinical parameters, were developed and used to diagnose and recommend therapy. The system, affectionately called HEADMED, had sound knowledge about the differential diagnosis of the major affective disorders and schizophrenia. The Psychopharmacology Advisor had perfunctory information concerning paranoid disorders and personality disorders. HEADMED also had skeletal knowledge about neuroses, behavior disorders, substance abuse, organic brain disorders, including both the type of brain disorder (e.g. delirium or dementia), and the cause of brain disorders (e.g. intoxication or trauma). The program has never known anything about child psychiatry, sexual disorders and other psychiatric conditions.

The HEADMED software had the capability of recommending a drug treatment, if indicated, and of cautioning about potentially harmful interactions with a compromised host and with other chemical substances. The system also could print out advice concerning dose and duration of therapy, pharmacokinetics, warnings about common side effects and possible adverse reactions.

Having been satisfied with the feasibility of using EMYCIN as a language for performing consultations in clinical psychopharmacology, our interest shifted to critically evaluating this application of EMYCIN and to modifying data structures and control mechanisms so that a a consultation process which is more natural, complete, and accurate occurs. We have also begun concentrating our attention on psychiatric disorders whose management might include prescription of a tricyclic antidepressant, one of the major classes of psychotherapeutic medications, and on outputting individual case-oriented advice and precautions concerning management and monitoring of a patient receiving a tricyclic antidepressant medication (see reference I.D.5 below). Thus we have begun to develop knowledge structures which can utilize this information to compute diagnostic formulations and therapeutic plans which are highly specific to the unique properties and circumstances of a particular patient.

We have discovered what we believe is an essential design problem for medical expert systems, that of controlling the amount and the type of information which the system requests from the user. This problem is inherent in medical expert systems because of the nature of the distribution of clinical states, and the nature of the training and the background of physicians. The problem also exists for human consultants, and a complete and general solution for computer systems is probably not achievable. However, several techniques show promise for reducing the magnitude of the problem in various clinical domains. These include system use of dynamic and static domain models, user control over sophistication level, and user access to the rationales behind information requests.

D. List of Relevant Publications.

1. Heiser, J.F., Brooks, R.E., and Ballard, J.P. Artificial Intelligence in Psychopharmacology. Abstracts - VI World Congress of Psychiatry, Honolulu, Hawaii, 28 August - 03 September 1977, page 135.

2. Heiser, J.F., Brooks, R.E., and Ballard, J.P. A Computerized Psychopharmacology Advisor. Continuing Medical Education Syllabus and Scientific Proceedings in Summary Form, The 131st Annual Meeting of the American Psychiatric Association, Atlanta, Georgia, 8-12 May 1978, American Psychiatric Association, Washington D.C., 1978, page 216.

3. Heiser, J.F., Brooks, R.E., and Ballard, J.P. A Computerized Psychopharmacology Advisor. The 11th C.I.N.P. Congress, Collegium Internationale Neuro-Psychopharmacologicum, 9-14 July 1978, Vienna, Austria, Book of Abstracts, page 233, c/o INTERCONVENTION, Kinderspitalgasse 5, A-1095, Vienna, Austria.

4. Heiser, J.F. and Brooks, R.E. Design Considerations for a Clinical Psychopharmacology Advisor. In Orthner, F.H. (ed.), Proceedings, The Second Annual Symposium on Computer Applications in Medical Care, 5-9 November 1978, Washington, D.C., Institute of Electrical and Electronics Engineers, Inc., New York, 1978, pages 278-286.

5. Cutler, N.R. and Heiser, J.F. The Tricyclic Antidepressants. Journal of the American Medical Association, vol. 240, pages 2264-2266 (Editorial comment on page 2287. Error retraction: "Corrections", vol.241, page 566. Letters to the Editor and replies, in press.)

6. Heiser, J.F., Colby, K.M., Faught, W.S., and Parkison, R.C. Can Psychiatrists Distinguish a Computer Simulation of Paranoia from the Real Thing? Tentatively accepted for for publication in the Journal of Psychiatric Research.

7. Brooks, R.E. and Heiser, J.F. Letter to the Editor, American Journal of Psychiatry (in press: vol. 136, page 857, June 1979), regarding the article Roberts, B.: A Look at Psychiatric Decision Making, American Journal of Psychiatry, volume 135, pages 1384-1387, 1978.

8. Heiser, J.F. Observations on Computerizing Clinical Psychopharmacology. Continuing Medical Education Syllabus and Scientific Proceedings in Summary Form, The 132nd Annual Meeting of the American Psychiatric Association, Chicago, Illinois, 14-18 May 1979 (in press).

9. Brooks, R.E. and Heiser, J.F. Controlling Question Asking in a Medical Expert System. Proceedings of of the 6th International Joint Conference on Artificial Intelligence, 20-23 1979, Tokyo, Japan (in press).

II. Interactions with the SUMEX-AIM Resource.

A. Collaborations and Medical Use of Programs via SUMEX.

The MYCIN group has collaborated with our group since work on the Psychopharmacology Advisor began. The MYCIN group supplies invaluable software support to the EMYCIN program. Our group has participated in writing documentation of the EMYCIN software which presumably is useful to all EMYCIN users.

B. Sharing and Interactions with Other SUMEX-AIM Projects.

Collaboration with Kenneth Mark Colby, M.D. and members of the Higher Mental Functions Project, begun two years ago, has continued in the form of writing and having (tentatively) accepted for publication a paper reporting a "Turing Test" which was performed on-line on SUMEX, with the psychiatrist-judges located at the University of California, Irvine, the patient-person at the University of California, Los Angeles (UCLA) and PARRY at SUMEX. Prepublication copies of this paper (see I.D.6. above: Heiser et al. Can Psychiatrists Distinguish a Computer Simulation of Paranoia from the Real Thing?) are available upon request. In addition, demonstrations of the PARRY and DOCTOR programs have been given on-line, using SUMEX, to various groups of mental health professionals, computer scientists and other qualified and interested individuals.

C. Critique of Resource Management.

We continue to find the SUMEX resource a hospitable environment. We feel that the choice of operating system and associated utilities was an unusually good one, and it has become a standard against which we judge other systems.

We strongly support the decision to continue with the Tymshare network service; the negative effects on our work of the unpredictable patterns of response delay in the Telenet service seemed disproportionate to the small cost savings. (We suspect that the difference in performance levels raises some fundamental issues about the suitability of packet switched networks for terminal-remote host communications.)

The situation we criticized last year, in regard to the documentation of the EMYCIN software, has improved substantially with the availability of document files on the system. This has had an extremely positive impact on our work in informing us of useful software features which we otherwise had no idea existed.